BUREAU OF RECLAMATION
Technical Service Center
Denver, Colorado

TRAVEL REPORT

Code : D-8560 Date: November 10, 2005

To : Manager, Water Resources Research Laboratory

From : Tony Wahl

Subject: Travel to Seattle, Washington to Participate in Meetings of CEA Technologies, Inc. (CEATI), Regarding Embankment Dam Breach Research

1. Travel period: September 12-15, 2005

2. Places or offices visited: Seattle, Washington - Seattle Municipal Tower

3. Purpose of trip: To chair a meeting of the CEATI working group on dam breach erosion and to report on project status to the CEATI Dam Safety Interest Group (DSIG).

4. Synopsis of trip: I traveled to Seattle, Washington on the afternoon of Monday September 12. The working group on dam breach erosion met on Tuesday and Wednesday to review the status of our ongoing project and develop proposals for new work to be pursued after the end of the current first phase of the research. A detailed meeting summary is attached. In brief, we developed a proposal for analysis of embankment breach test data collected in Norway during 2002 and 2003, and we developed a tentative proposal for development of a new embankment dam breach model in a three-year project that would begin in the summer of 2006. Our strategy for model development is to make use of technology currently under development at the Agricultural Research Service laboratory in Stillwater, Oklahoma, and to create a model that operates within the existing HEC-RAS software suite. For that purpose we will be seeking additional involvement of the U.S. Army Corps of Engineers (USACE) in our working group.

On Thursday morning I presented our proposals to the full DSIG where they were well received. I discussed additional USACE involvement with Mr. Charles Pearre, USACE Dam Safety Program Manager, and he agreed to initiate discussions within USACE on how best to coordinate our work. This is an especially timely topic within USACE due to the recent breach of levees in the New Orleans area as a result of hurricane Katrina.

I returned to Denver on Thursday afternoon.

Travelers: Wahl Date: November 10, 2005

5. Conclusions: The meeting was very productive and produced significant new research and development proposals. The group outlined a strategy for developing an embankment dam breach model that will utilize the best available technology and can continue to improve in the future as new developments warrant.

6. Action correspondence initiated or required: None

cc: D-1440 (Becker)

bc: D-8560 (Travel Report file)

Attachment

SIGNATURES AND SURNAMES FOR:

Travel to: Seattle, Washington

Date or Dates of Travel: September 12-15, 2005

Names and Codes of Travelers:

Traveler	Date
Tony L. Wahl	11/10/05

Noted and Dated by:

Signature	Date
[signature]	11/10/05

CEATI Dam Safety Interest Group (DSIG)

Dam Breach Erosion Working Group Meeting

Dates: September 13-14, 2005

Location: Seattle, Washington, USA
Seattle Municipal Tower, 700 5th Avenue
Room 4540

Participants: Jean-Robert Courivaud, Electricité de France
Greg Hanson, USDA-Agricultural Research Service
Allan Kirkham, Ontario Power Generation
Tony Wahl, Bureau of Reclamation
Gary Salmon, CEATI-DSIG
Chris Hayes, CEATI (Sept. 14 only)
Due to a scheduling mixup, representatives from Hydro Québec were not in attendance, but Tai Mai Phat (Hydro Québec) and René Kahawita (École Polytechnique) did attend the regular DSIG meeting on Sept. 15-16.

Summary: We met for two days with the primary purpose of developing proposals necessary to complete the first phase of the project and advance into the second and later phases. The products of the meeting were tentative proposals for:

- Completing the analysis of data collected from Norwegian dam breach tests
- Phase 2 of the Dam Breach Erosion Project focusing on development of an improved dam breach model

We began the meeting by reviewing the status of the phase 1 project and the recent work of the Agricultural Research Service. In the afternoon of the first day we developed tasks, a tentative budget, and a tentative schedule for analyzing the Norwegian Dam Breach data. On the second day we developed the proposal for Phase 2 of the project. Details of each proposal and action items are given below. The proposals were presented to the full meeting of the DSIG on the morning of September 15.

Analysis of Data from Norwegian Dam Breach Tests

Large-scale embankment breach tests were conducted in Norway during 2002 and 2003. Several 6-m high dams were breached to study details of the breaching process and to complement other small-scale laboratory breach tests being performed as part of the European Union IMPACT project. Although some aspects of the tests were difficult to control and may have been less than ideal, these are still potentially some of the most well-documented case studies of dam failure at large scale. They would be very valuable for validation testing of any new breach model that this project might develop. Unfortunately, the Norwegian organizations that performed the tests have exhausted most

of their funding and have not been able to complete the analysis of all of the test data. The full series of tests is estimated to have cost $3M CAD to conduct. Completing the data analysis would cost a fraction of that.

The testing included the following (bold-faced items could provide useful data):

- 5 Overtopping Tests
  - Homogeneous rockfill…shakedown test only, no data
  - **Homogeneous moraine embankment (cohesive)**
  - **Homogeneous gravel with rock downstream slope (rock slope was removed prior to overtopping)**
  - Homogeneous rockfill…did not breach
  - **Zoned rockfill with central moraine (cohesive) core**

- 2 Piping Tests
  - **Rockfill dam with central moraine core**
  - **Homogeneous moraine (cohesive) dam**

The collected test data included the following:

- Inflow/outflow hydrographs
- Upstream & downstream water level records
- Pore pressure sensors, 8 per dam
- Embedded breach detector instruments (about 100 per dam)
- Material properties measurements
- Photo/video records, 54 DVDs

All of the raw data are now in the possession of EDF and Hydro Québec, who purchased it from the Norwegian organizations. Analysis of the data could thus proceed without assistance from the Norwegians, but all of the members of the working group concurred that it would be in everyone's best interest to have the Norwegians involved due to their familiarity with the test conditions and the data, and their interest in seeing the data put to best use. Initial inquiries have been met with positive reactions from the Norwegians. We compiled a tentative list of the tasks we felt needed to be completed.

1. Construct breach size vs. time record using the data from the tilt sensors and the video records. (Norwegians have video software)
2. Review inflow/outflow hydrographs and check for consistency with breach size
3. Write descriptive record of each test from videos and photos
4. Document unique test details
5. Document and summarize material properties data
6. Interpretation of test data to infer k_d values (detachment rate coefficient)
7. Summarize and check pore pressure sensor data
8. Final Report

The first task is more efficiently performed using specialized video software that the Norwegians have already purchased. We believe some analysis of the videos has already

been performed, and the best approach to this task would probably be for the Norwegians to continue and complete it. If this cannot be done, we would like to determine whether the software could be given or loaned to another party (perhaps EDF) so that they could complete the analysis.

Task 2 was specifically listed because those familiar with some of the tests and the data have noted some possible inconsistencies in the various inflow and outflow hydrographs and reservoir level records. The inconsistencies need to be investigated so that we can determine the best data for future use and identify any data that should not be used in the future. Some of these inconsistencies may be explained with a better understanding of some of the unique test details (Task 4), such as periods during which overtopping occurred in areas other than the planned test section.

Task 6 would consist of an iterative application of the ARS SIMBA (SIMplified Breach Analysis) model for the purpose of inferring an appropriate value of the detachment rate coefficient, k_d for the materials used in each test. This is a very experimental procedure requiring significant judgment to determine when model results "best" match the experimental data. It should be recognized that some of the embankment materials are essentially cohesionless and are thus dramatically different than the materials for which SIMBA was developed and for which values of k_d are already well established.

We developed a tentative budget and schedule for the project, summarized in the following spreadsheet.

Analysis of Norwegian dam breach test data

Estimated staff-day cost
$ 1,150 CAD

Task	Estimated Staff-days	Who?	In-kind $ CAD	Cash $ CAD	Total $ CAD	Schedule Start Jan. 2006 (X=1 quarter)			
Review inflow/outflow hydrographs	15	HQ/USBR	$ 17,250		$ 17,250	X			
Construct breach size vs. time record – tilt sensors	15	EDF/ Norwegians	$ 8,625	$ 8,625	$ 17,250	X			
Construct breach size vs. time record – videos (Norwegians have video software)	30	EDF/ Norwegians	$ 17,250	$ 17,250	$ 34,500	X			
Check for consistency between outflow hydrograph and breach size	5	HQ/USBR	$ 5,750		$ 5,750		X		
Write descriptive record of each test from downstream videos and photos	5	Norwegians		$ 5,750	$ 5,750	X	X		
Document unique test details	5	Norwegians		$ 5,750	$ 5,750	X	X		
Document and summarize material properties data	5	ARS	$ 5,750		$ 5,750			X	
Interpretation of test data to infer k_d values (detachment rate coefficient)	30	ARS	$ 34,500		$ 34,500			X	
Summarize pore pressure sensor data, check for consistency	5	HQ/USBR	$ 5,750		$ 5,750		X		
Final Report	5	All	$ 5,750		$ 5,750				X
Project Management	5	USBR	$ 5,750		$ 5,750	X	X	X	X
			$ 106,375	$ 37,375	$ 143,750				

Several questions could not be resolved during the meeting because we could not get into contact during the meeting with the Norwegian groups that conducted the tests and might

assist with the analysis of the data. These questions should be resolved shortly, and the proposal refined to reflect likely participation by the Norwegians.

- Have any of the identified tasks already been partially or fully completed by the Norwegians, or will they be completed as part of their ongoing efforts to wrap up the dam breach project?

- Would they suggest modifying any of our estimates or adding or deleting any tasks?

- Can the Norwegians complete the video analysis (with specialized software they already have), or give or loan the software to EDF so that they could complete the analysis?

- We would like the products of the proposed analysis to be incorporated into the EDF case study database and made available to the public. Does this raise any issues for the Norwegians or any of the other groups that originally participated in and funded the tests?

Dam Breach Erosion Project: Phase 2 – Model Development

The dam breach erosion project is expected to ultimately be a three phase project. The current project, Phase 1, is focused on three tasks of information gathering and evaluation. To review, dam breach case study data is being compiled for future use in verification and validation testing of any new models. Second, a database of laboratory testing is being compiled to summarize the available test data and identify gaps that might need to be filled in the future. Finally, existing numerical models are being evaluated to identify those potentially worthy of future development during the later phases of the project.

We assembled a list of desirable capabilities and features for the model:

- Full metric and English unit support.
- Simulate erosion caused by overtopping flow to determine the degree of overtopping that might be allowed by designers seeking to utilize the embankment as an emergency spillway (i.e., determine an amount of overtopping that causes minimal damage).
- Simulate breaches of homogeneous, cohesive embankments that fail due to overtopping.
- Simulate breaches of rockfill dams.
- Simulate breaches initiated by piping.
- Simulate breaches of zoned embankments. A model for homogeneous cohesive embankments might be applicable to zoned embankments with a traditional, thick, central clay core, since the clay core would predominantly control the erosion rate. Zoned embankments with inclined cores might be effectively modeled as modified rockfill dams.

- Integration of breaching model with associated models used in the overall dam break analysis process (e.g., downstream flood routing models and the tools used to assess consequences of dam failure).

Some of the capabilities described above are already present to some degree in the models that are now under development by the Agricultural Research Service. Their WinDAM model is presently available in an alpha-test version for analyzing the "limited overtopping" scenario (WinDAMa) for vegetated embankments, and capability to analyze riprap-protected embankments is also planned. A version still under development (WinDAMb, due for alpha-test release in summer 2006) will add the capability to model the overtopping breach of homogeneous, cohesive embankments. The WinDAMb model will incorporate the modeling technology already available in ARS's research model, SIMBA. The ARS models do not provide metric unit support at this time, and they utilize a simple level-pool reservoir routing scheme that ARS has expressed interest in improving.

The ARS breach models are viewed by the members of the working group as having a well-balanced combination of the following characteristics:

- computational simplicity
- good representation of the overall embankment breach process
- erosion models that appropriately represent the observed physical processes and are based on material properties that can be measured or estimated by practical means
- supported by carefully planned and conducted large-scale physical testing

In addition, as products of the US government, the ARS models are available in the public domain, so their technologies could be incorporated into a model that CEATI might develop. Greg Hanson expressed the willingness of ARS to participate with CEATI in such a development project. This led us to outline potential second and third phases of the project as follows:

- Phase 2 - Create a new model or improve an existing model that would meet some, but not all of our long-term goals. This model is likely to be useful for analyzing breaches of homogeneous, cohesive embankments that fail due to overtopping, and with simplifying assumptions could possibly be applied to some zoned embankments. This model would be similar to the WinDAMb model, with some improvements such as metric unit support, and possibly improved reservoir routing.

- Phase 3 - Add further capabilities to the model, such as the analysis of rockfill embankments and more complex zoned embankments, and the analysis of breaches initiated by piping.

This plan would of course evolve based on the final results of CEATI's Phase 1 effort, in particular the investigation into numerical models.

We spent some time discussing organizational strategies for model development and how we might achieve integration with associated dam-break analysis tools. A key decision that must be made is who will lead the development of the code and where it will reside after development is complete. This decision will affect the long-term maintenance and improvement of the model as computer technology and breach modeling technology continue to evolve. If long-term maintenance and improvement do not occur, the model is likely to have a relatively short lifespan.

Potential "homes" for the model include of course the primary partners in the work to date: ARS, the Bureau of Reclamation, EDF, and Hydro Québec. The working group felt that none of these organizations were in the best position to provide long-term maintenance and improvement of the model, nor integration of the model with other tools commonly used in analyzing dam-break scenarios. Our respective organizations all tend to view software development as a one-time activity, with future maintenance and improvement usually requiring new justification. We really need an organization with an established commitment to maintaining and improving software for the benefit of the water resources engineering profession.

After discussing many alternatives, we concluded that the best place for the software to reside is with the U.S. Army Corps of Engineers (USACE), conveniently a fellow CEATI member and a financial contributor to Phase 1 of this project. Their HEC-RAS software and other associated HEC models are some of the most widely used hydraulic engineering analysis tools, and already have basic dam-break modeling capabilities, along with well-designed and maintained user interfaces. USACE has expressed some interest in the past in the ARS work on dam breaching and they have recently adopted related ARS technology for modeling earthen spillway headcut erosion (Sites Spillway Erosion Analysis, SSEA). To achieve the integration of a new breach model into the HEC software suite, it is critical that we have membership in the working group from key personnel at USACE and the Hydrologic Engineering Center. A summary of advantages for this strategy include:

- USACE has an established track record of producing hydraulic analysis tools for everyone's benefit
- USACE and the HEC have a demonstrated commitment to maintenance and improvement, as shown by the recent release of HEC-RAS.
- Adoption of the technology by USACE would minimizes future maintenance issues for CEATI and the DSIG
- Achieves integration with related modeling tools and user interface
- Brings additional technical talent to bear on the task

There are also some disadvantages to incorporating the breach modeling tools with the HEC models:

- Loss of control of the model

- Model would not be easily accessible to people using non-HEC models for dam break analysis (e.g., MIKE11, SOBEK), although the technology would be public and thus could be incorporated into other models in the future.

The members of the working group were in agreement that the advantages far outweigh the disadvantages and that integration with HEC software is the best possible approach. To develop a preliminary project plan, we identified the following primary tasks for the Phase 2 project:

- In-depth review and selection of most promising models, using results of Phase 1

- Develop dam breach model
    - Computational part (primarily ARS)
    - Interface (primarily USACE)

- Validation and verification
    - Compare to case studies
    - Assessment of uncertainty
    - Sensitivity analysis

- Improve methods for measuring material parameter inputs (e.g., erodibility) in the field and the lab (USBR, ARS, EDF)

We feel that the last task is especially important because small changes in material parameters such as compaction and moisture content can have a dramatic effect on erodibility. Both field (in situ) and laboratory methods for measuring erodibility are needed because in situ methods can only evaluate erodibility in accessible portions of the embankment, generally near the surface. Laboratory methods might also include portable equipment that could be applied in the field to undisturbed samples collected from within an embankment. A proposal to make a comparative evaluation of existing methods for measuring erodibility of cohesive materials has already been submitted to the Bureau of Reclamation Science & Technology Program. If funding from this source is not received, we will seek funding from other sources.
A more detailed task list with tentative work assignments, cost estimates, and schedules is shown in the spreadsheet on the next page. Key points to keep in mind about this estimate are that:

- Most of the work consists of in-kind efforts of the project partners
- Majority of the cash funding shown is to cover contingencies
- There is a half-year of extra time in the tentative schedule
- The tentative estimate and schedule do not include the time and cost for development of documentation, manuals, and training materials

The tentative plan was presented to the DSIG on September 15. The first steps to implement the strategy developed during this meeting are:

- Get greater involvement of the USACE in the working group, hopefully by adding a member from the HEC, and perhaps also Johannes Wibowo from the ERDC.

- Review the proposal with respective program managers for each of the in-kind contributors

- Prepare written project plan incorporating any revisions necessary

Meeting summary prepared by Tony Wahl

Task	Who Could Do This Work?	Time (Staff-Days)	Budget	EDF	USBR	OPG	ARS	HQ	USACE	In-kind	Cash	Schedule, starting July 2006 X = one quarter
												XX | XXXX | XXXX | XX
In-depth review of most promising models	Working group	40	$ 46,000	$ 7,667	$ 7,667	$ 7,667	$ 7,667	$ 7,667	$ 7,667	$ 46,000		X. | .... | .... | ..
Select model(s)	Working group	40	$ 46,000	$ 7,667	$ 7,667	$ 7,667	$ 7,667	$ 7,667	$ 7,667	$ 46,000		.X | .... | .... | ..
Develop computational model	Working group, USACE, algorithm developers	60	$ 69,000	$ 3,450	$ 3,450	$ 3,450	$ 51,750	$ 3,450	$ 3,450	$ 69,000		.. | XX.. | .... | ..
Specifications for interface	Working group	15	$ 17,250	$ 2,875	$ 2,875	$ 2,875	$ 2,875	$ 2,875	$ 2,875	$ 17,250		.. | XX.. | .... | ..
Develop Interface (USACE)	USACE	60	$ 69,000	$ -	$ -	$ -	$ -	$ -	$ 69,000	$ 69,000		.. | ..X. | .... | ..
Verification and validation (against case studies), assuming 7 case studies that could be used	Working group, code developers	70	$ 80,500	$ 23,000	$ 23,000	$ 11,500	$ 11,500	$ 11,500	$ -	$ 80,500		.. | ...X | .... | ..
Assessment of uncertainty	One or more working group organizations, EDF and ARS expressed particular interest	40	$ 46,000	$ 23,000	$ -	$ -	$ 23,000	$ -	$ -	$ 46,000		.. | .... | XX.. | ..
Sensitivity analysis	One or more working group organizations, ARS	40	$ 46,000	$ -	$ -	$ -	$ 46,000	$ -	$ -	$ 46,000		.. | .... | XX.. | ..
Improve methods for measuring material parameter inputs (e.g., erodibility) in the field and the lab	ARS/USBR/EDF	200	$ 230,000	$ 34,500	$ 172,500	$ -	$ 23,000	$ -	$ -	$ 195,500	$ 34,500	XX | XXX. | .... | ..
Identify future research & development needs	Working group	Included	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -		.. | .... | ..X. | ..
Documentation, manuals	Working group, USACE		$ -							$ -		.. | .... | XX.. | ..
Training	Working group, USACE		$ -							$ -		.. | .... | ..XX | ..
Project management	USBR	60	$ 69,000	$ -	$ 69,000	$ -	$ -	$ -	$ -	$ 69,000		XX | XXXX | XXXX | XX
Contingencies											$115,500	
TOTAL		625	$ 718,750	$ 102,158	$ 286,158	$ 33,158	$ 173,458	$ 33,158	$ 90,658	$ 684,250	$150,000	